CLAIMS

What is Claimed is:

1. Apparatus for construction of a soil reinforcement pier in a soil matrix comprising, in combination:

an elongate hollow tube having a longitudinal axis, a top material entrance end, an open bottom material discharge end; and

a shaped bottom head element for the open discharge end configured to provide axial and transaxial stress components onto the soil matrix surrounding the bottom head element upon lowering the hollow tube into the soil matrix, said head element including a sacrificial cap removable from the hollow tube discharge end upon upward movement of the hollow tube within a soil matrix, said bottom head element and hollow tube being shaped for insertion in a soil matrix to effect displacement of the soil as the hollow tube is lowered into the soil matrix to form a cavity in the soil matrix and the cap being disengageable from the bottom head element as the hollow tube is subsequently raised from the bottom of the formed cavity.

2. Apparatus for construction of a soil reinforcement pier in a soil matrix comprising, in combination:

an elongate hollow tube having a longitudinal axis, a top material entrance end, and an open bottom material discharge end;

a shaped bottom head element comprising the open discharge end configured to provide axial and transaxial stress components onto the soil matrix surrounding the head element upon lowering the hollow tube into the soil matrix, said bottom head element being attached to the hollow tube and including a mechanism for closing and opening the discharge end of the hollow tube.

3. The apparatus of claim 1 or 2 further including a fluid feed mechanism for directing a fluid material into the hollow tube and a solid material feed mechanism for feeding aggregate material into the hollow tube entrance end.

4. The apparatus of claim 1 or 2 wherein the hollow tube has a generally circular internal cross section and further including an aggregate feed mechanism connected to the top material entrance end for feeding items of aggregate material wherein the minimum size of the internal diameter of the hollow tube is at least 4.0 times the maximum size dimension of the largest item of aggregate material.

5. The apparatus of claim 1 or 2 or 7 or 8 further including at least one auxiliary feed tube connected to the hollow tube through openings in the hollow tube end for feeding fluid material into the hollow tube.

5A. The apparatus of claim 1 or 2 or 7 or 8 further including at least one auxiliary feed tube connected to the hopper for feeding liquid material into the hollow tube.

6. The apparatus in claim 1 or 2 wherein the external cross sectional area of the hollow tube is varied along the longitudinal length of the hollow tube with the cross sectional area of the bottom head element being greater than the cross sectional area of the remainder of the hollow tube.

7. Apparatus for construction of a soil reinforcement pier in a soil matrix comprising, in combination:

an elongate hollow tube having a longitudinal axis, a top material entrance end, an open bottom material discharge end; and

a valve device for opening and closing the open discharge end for discharge of aggregate therefrom upon opening of the discharge end, said hollow tube and valve device being insertable in a soil matrix by displacement of the soil as the hollow tube is lowered into the soil matrix with the valve device in the closed position, and said valve

device including a mechanism to open the valve device upon subsequent raising of the hollow tube to discharge aggregate into a cavity region of soil matrix vacated by the hollow tube.

8. Apparatus for construction of a soil reinforcement pier in a soil matrix comprising, in combination:

an elongate hollow tube having a longitudinal axis, a top material entrance end, an open bottom head element discharge end, the external cross section of the bottom head element discharge end being greater than the external cross section of the hollow tube adjacent thereto to thereby form a bulbous section of the hollow tube having a cross sectional shape and size greater than the cross sectional shape and size of the hollow tube adjacent the bulbous end; and

a mechanism for selectively closing and opening the discharge end of the hollow tube.

9. The apparatus of claim 8 further including a shaped bottom head element at the discharge end, said head element configured to provide simultaneous axial and transaxial stress components on soil matrix material surrounding the head element upon axial reciprocation of the hollow tube in the soil matrix.

10. The apparatus of claim 8 or 9 wherein the mechanism for selectively closing and subsequently opening comprise a sacrifical cap affixed to the shaped bottom head element of the hollow tube.

11. The apparatus of claim 8 or 9 wherein the mechanism for selectively closing and opening comprise a valve device.

12. The apparatus of claim 8 or 9 wherein the mechanism for selectively closing and opening comprise a valve device that opens by gravity and closes by contacting aggregate material in the soil matrix upon downward movement of the hollow tube.

13. The apparatus of claim 9 wherein the head element comprises a frustoconical element formed on the discharge end of the hollow tube.

14. The apparatus of claim 8 wherein the internal cross section of the hollow tube is generally circular and has an internal diameter greater than about 4.0 times the maximum dimension of aggregate particles fed into the hollow tube.

15. The apparatus of claim 1 or 2 or 7 or 8 further including passageway openings in the hollow tube above the bottom head element for fluid materials within the hollow tube to flow out of the hollow tube above the bottom head element and outside of the hollow tube into an annulus formed between the hollow tube and the soil matrix.

16. The apparatus of claim 1 or 2 or 7 or 8 further including a hopper feed mechanism connected to the top material entrance end of the hollow tube.

17. The apparatus of claim 15 further including at least one isolation damper connecting the hopper to the hollow tube to reduced vibration forces on the hopper feed mechanism.

18. The apparatus of claim 5 further including a mechanism for selectively opening and closing the liquid feed tube.

19. The apparatus of claim 15 further including a mechanism for selectively opening and closing the passageway openings.

20. The apparatus of claim 1 or 2 or 7 or 8 further including an auxiliary feed passage to the hollow tube for feeding a fluid material to the hollow tube selected from the group consisting of water, cementitious grout, bentonite, fly ash and combinations thereof.

21. The apparatus of claim 1 or 2 wherein the shaped bottom head element is beveled.

22. The apparatus of claim 7 wherein the valve element includes a beveled external surface.

23. The apparatus of claim 1 wherein the sacrificial cap element is generally hexagonal.

24. The apparatus of claim 1 or 2 or 7 or 8 further including a force mechanism connected to the hollow tube for providing a force on said hollow tube.

25. The apparatus of claim 1 or 2 or 7 or 8 further including a force mechanism connected to the hollow tube for providing a static axial force of typically between five tons and twenty tons.

26. the apparatus of claim 1 or 2 or 7 or 8 including a force mechanism for providing an optional force on the hollow tube selected from the group consisting of a vertically reciprocating force, a vertically vibrating dynamic axial force, and combinations thereof.

27. The apparatus of claim 1 wherein the sacrificial cap element comprises a transaxial plate member for retention within the formed cavity and a rod member extending from the plate member into the hollow tube.

28. The apparatus of claim 27 wherein the plate and rod member comprise a test element.

29. The apparatus of claim 27 wherein the plate and rod member comprise an uplift anchor pier element.

30. The apparatus of claim 1 or 2 or 7 or 8 wherein the hollow tube has a generally constant cross sectional profile.

31. A method for forming a pier in a matrix soil comprising the steps of:

a) forming an elongate cavity having a bottom and a longitudinal axis in the matrix soil by forcing a hollow tube having an open top end and an open bottom head element with a closure mechanism for selectively closing the hollow tube, said bottom head element configured to provide axial and transaxial vector forces on the soil matrix, said closure mechanism maintaining material discharge from the bottom head element closed during formation of the cavity;

b) raising the hollow tube a first incremental distance in the cavity;

c) opening the closure mechanism while the hollow tube is raised;

d) feeding aggregate through the bottom head element of the hollow tube into the portion of the cavity revealed by raising the hollow tube said first incremental distance; and

e) compacting the aggregate in the cavity by axial and transaxial force impacted thereon from the shaped bottom head element as the hollow tube is lowered.

32. The method of claim 31 wherein the hollow tube is initially forced a predetermined distance into the matrix soil.

33. the method of claim 31 wherein step b) is a predetermined distance.

34. The method of claim 31 including the repetition of steps b) through e).

35. The method of claim 31 including the step of closing the closure mechanism before compacting.

36. The method of claim 31 including the additional step of separately feeding a liquid material in combination with the aggregate to facilitate aggregate flow.

37. The method of claim 36 wherein the liquid material is selected from the group consisting of water, cementitious grout, bentonite, cement, fly ash, and combinations thereof.

38. The method of claim 36 wherein the liquid material is fed into the hollow tube.

39. The method of claim 36 wherein the liquid material is fed into the hopper.

40. The method of claim 36 wherein the liquid material is fed from the hollow tube.

41. The method of claim 36 wherein the liquid material is fed into the cavity from a feed mechanism that feeds the liquid in an annular pattern above the bottom head element, near the bottom end of the hollow tube.

42. The method of claim 31 wherein the hollow tube has a uniform internal cross section.

43. The method of claim 31 wherein the bottom head element has an external cross section greater than the external cross section of the remainder of the hollow tube.

44. The method of claim 31 including the step of feeding aggregate from a hopper into the top end of the hollow tube.

45. The method of claim 32 including the step of providing a static force on the hollow tube to effect driving of the hollow tube and to effect compacting aggregate.

46. The method of claim 32 including the step of providing a dynamic axial force on the hollow tube to effect driving of the hollow tube and to effect compaction of aggregate.

47. The method of claim 31 or 32 including the additional step of preloading a formed pier.

48. The method of claim 28 or 32 wherein the step of compacting comprises reducing the axial dimension to about ¾ to 1/5 of the uncompacted aggregate first incremental distance to form a compacted aggregate having a vertical axial dimension of about ¾ to $^{1}/_{5}$ of the first incremental distance.

49. The method of claim 42 or 43 including the step of placing an axial rod and plate in the hollow tube said rod extending upwardly from said plate.

50. The method of claim 31 including the step of repeating steps c) through e).

51. The method of claim 32 wherein the first incremental distance is varied for at least one of the repetitions.

52. The method of claim 57 including at least three repetitions.

53. The method of claim 31 wherein the first incremental step is substantially equal to the height of the pier to be formed.

54. The method of claim 31 wherein the first incremental step is less than the height of the pier to be formed.

55. The method of claim 31 wherein the first incremental step is greater than two feet and less than the height of the pier to be formed.

56. The method of claim 31 wherein the step (e) comprises compacting to effect movement of the bottom head element substantially to the bottom of the cavity.

57. A method for forming a pier in a matrix soil comprising the steps of:

(a) forming an elongate cavity having a bottom and a longitudinal axis in a matrix soil by positioning a hollow tube with a head element into the matrix soil to a predetermined depth, said head element configured to impart axial and transaxial forces on the matrix soil;

(b) raising the hollow tube an incremental distance from the bottom of the cavity;

(c) feeding pier forming material through the hollow tube into the cavity upon raising of the tube; and

(d) compacting the pier forming material with the head element by driving the hollow tube downwardly toward the bottom of the cavity while displacing pier forming material transaxially in the cavity.

58. Apparatus for construction of a soil reinforcement pier in a soil matrix comprising, in combination:

an elongate hollow tube having a longitudinal axis, a top material entrance end, an open bottom head element discharge end, the external cross section of the bottom head element discharge end being greater than the external cross section of the hollow tube adjacent thereto to thereby form a bulbous section of the hollow tube having an external cross sectional shape and size greater than the external cross sectional shape and size of the hollow tube adjacent the bulbous end; and

said bulbous end having a surface configured to impart axial and transaxial forces upon downward movement on material.